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OXIDE CHARACTERIZATION PICKERING "A" FEEDERS

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ABSTRACT

The oxides on six Pickering "A" feeders were examined. Results show that the last decontaminations at Units 1 and 2 in 1984 effectively removed about 90% of oxide from the inlet feeders. During the next decontamination carried out at Unit 3, it is estimated that similar amount of oxide would be removed from the inlet feeder provided the inlet oxide behaves the same way as that on the Units 1 and 2. However, the concentrations of trace elements such as Cr, Cu, Ni and Zn in the oxide near the water/oxide interface were significantly higher than those in the earlier Units 1 and 2 feeders. This could possibly affect the rate of oxide dissolution during a decontamination.

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EXECUTIVE SUMMARY

OXIDE CHARACTERIZATION - PICKERING "A" FEEDERS

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The oxides on six Pickering "A" feeders were examined to identify whether the oxide character could play a major role in limiting the effectiveness of decontamination and to support the planned Unit 3 decontamination (CAN-DECON) in 1989.

Results suggest that the last two decontaminations in Units 1 and 2 effectively removed about 90% of oxide from the inlet feeders. Hence, similar amount of Unit 3 inlet oxide will likely be removed during the 1989 decontamination provided the oxide behaves the same way as the oxide on Units 1 and 2 feeders.

However, the concentrations of some trace elements in the Pickering oxides were significantly higher than those in the earlier Pickering feeders. This increase could possibly contribute to the slower oxide dissolution observed near the end of full scale decontaminations. Hence, an additional oxidizing step may improve the effectiveness of the decontamination.

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32-148-551	836.29	May 17 1989	89-3-K

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OXIDE CHARACTERIZATION - PICKERING "A" FEEDERS

V.S. Chew

INTRODUCTION

Oxides on the Pickering 1 V17 inlet and outlet feeders, Pickering 2 A12 inlet feeder and V17 outlet feeder and Pickering 3 V17 inlet and outlet feeders were examined. The information will be (1) compared to the earlier results to identify whether the oxide character plays a major role in limiting decontamination radiation field reductions, and (2) used to estimate the total Co-60 and oxide inventory on the carbon steel surfaces and IX resin requirements for the planned Unit 3 decontamination in 1989.

Analytical techniques employed include SEM (scanning electron microscopy) to determine the surface morphology; EDAX (energy dispersive X-ray fluorescence spectrometry) to identify the inactive elements on the oxide; XRD (X-ray diffraction) to identify the structure of the oxide (whether the iron-oxide is magnetite or hematite); gamma spectrometry and atomic absorption spectrophotometry to obtain the depth profiles of both radioelements and inactive elements.

HISTORY

The Unit 1 feeders were exposed to decontaminations in 1981, 1983 and 1984. The Unit 2 feeders were exposed to two decontaminations in 1984. Unlike the Units 1 and 2 feeders, the Unit 3 feeders were exposed to operating conditions after the 1985 decontamination before their removal in April 1988.

RESULTS AND DISCUSSION

1. Appearance

The cross-sections and the surface morphology of the six Pickering feeder samples are shown in Figures 1 to 9.

A. **Pickering 1 V17 inlet feeder:** The surface is oxide covered. The oxide thickness is about 5 um. Ink bottle shaped pits (pit depth about 40 um, Figure 1), as well as round and shallow pits (up to 200 um wide, Figure 4) were found on the surface. SEM micrograph also shows that the oxide surface is quite uneven.

B. **Pickering 1 V17 outlet feeder:** The surface is not uniformly covered with oxide and oxide was found in the bottom of pits (Figure 1). The cross section also shows that the surface is very pitted and the pits are elliptical. SEM shows that the opening of the pits is irregular in shape (Figure 5).

C. **Pickering 2 A12 inlet feeder:** The surface is pitted, but is still covered by about 5 um thick oxide (Figure 2). SEM shows the pits on this surface have propagated resulting in larger pits (Figure 6).

D. **Pickering 2 V17 outlet feeder:** The surface is covered by about 10 um thick oxide. Wide and shallow pits as well as smaller pits are observed (Figure 2). Isolated, deep pits not shown here were reported earlier (pit depth up to 400 um)/1/. Figure 7 shows large particles (as wide as 100 um) are deposited on a dense oxide. EDAX indicates that iron is the major component of the large particles (the amount of Cr and Mn found on the particle is significantly less than that on the bulk oxide).

E. **Pickering 3 V17 inlet feeder:** The surface is completely covered with a layer of oxide about 25 um thick (Figure 3). But the oxide/base metal interface is not smooth (pits are oxide filled). SEM shows that the surface is covered by sub-micron particles (up to 1 um in size) with larger iron oxide particles (identified by EDAX) deposited on them (Figure 8).

F. **Pickering 3 V17 outlet feeder:** The surface is covered by about 5 um thick oxide (Figure 3). Both ink bottle shaped (pit depth about 75 um) and elliptical pits were observed. SEM shows that the surface is severely pitted and pit opening is round (Figure 9).

The Units 1 and 2 feeders were not exposed to operating conditions after the decontamination(s) whereas the Unit 3 feeders were exposed to 3 years operating conditions after the decontamination. The oxide on all of these samples is not more than 25 um thick. This is considerably thinner than the 50 to 120 um thick oxide observed on the only inlet feeder sample that was not exposed to a decontamination (Unit 2 V17 inlet feeder)/2/. This suggests the oxide, at least on the inlet feeder, is effectively removed by the CAN-DECON decontamination.

In addition, rough oxide/base metal interface was observed on the Pickering 2 V17 inlet feeder and must have been caused by coolant chemistry since this feeder had not been exposed to any decontaminations/1/. On the other hand, localized corrosion observed on all of the feeders exposed to decontamination(s) may have been initiated by coolant chemistry and/or aggressive decontamination conditions (such as low pH in April 1984 decontamination).

2. Oxide Thickness

XRD identifies that the oxides on all six feeder samples are magnetite or closely related spinels/3/.

The amount of loose and fixed oxides on the four feeder samples was determined. The results together with previous feeder results/2,4/ are tabulated in Table 1 and plotted in Figures 10 and 11. Note that the Pickering Unit 1 V6 feeders were removed before the 1984 decontamination and about one year after the 1983 decontamination, the Unit 2 V17 inlet feeder before the 1984 decontaminations, and the Unit 2 V6 feeders between the January 1984 and the April 1984 decontaminations.

A. **Inlet feeders:** Figure 10 shows that the amount of oxide on an inlet feeder decreases after every decontamination. The thicker oxide on the Unit 3 feeder compared to those on the Unit 1 V17 and Unit 2 A12 feeders does not necessarily mean that the last Unit 3 decontamination was not as effective as the last Units 1 and 2 decontaminations because additional oxide was grown on the Unit 3 feeder during the 3 years operation after the decontamination.

   Although the oxide on Unit 3 inlet feeders will continue to grow until the outage prior to the 1989 decontamination, it is not expected that the oxide will be thicker than those on the V6 inlet feeders. Hence, if the Unit 3 inlet oxide behaves the same way as the oxide on these feeders during their last decontamination, about 90% of oxide is expected to be removed from the inlet feeders.

B. **Outlet feeders:** Figure 11 shows that the amount of oxide on an outlet feeder increases after the last Unit 1 decontamination. This was also observed on the in-service carbon steel coupons. Since during a decontamination the "original" feeder oxide could be removed/dissolved by the reagent, and at the same time "new" oxide forms on the feeder due to corrosion of the base metal or be deposited on the surface*, the residual oxide on a feeder consists of a

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* Iron-59 tracer measurements during the Unit 2 January 1984 decontamination showed that surface films formed on polished carbon steel coupons during the decontamination were not the result of deposition of circulating particulates but were produced by reaction between solution and the metal/5/.

mixture of the "original" oxide and the newly formed oxide. The increase in the amount of oxide on an outlet feeder and in-service coupons indicates that the amount of oxide removed is less than the amount of oxide formed. On the other hand, a net loss of fixed oxide is usually observed on an inlet feeder suggesting the amount of oxide removed by the reagent is significantly greater than the amount of oxide formed on an inlet feeder during a decontamination.

Assuming all of the "original" oxide on an outlet feeder is removed during a decontamination, results in Table 7 suggest that 10 to 30 g/m^2 of oxide could have been formed on an outlet feeder during a decontamination. This is similar to the amount of oxide found on the polished carbon steel coupons after decontamination(s).

3. Radioisotope Concentration

Radioisotope concentrations on the four feeder samples were determined/6/. The results tabulated in Tables 2 to 5 were decay corrected to shutdown. Since the Units 1 and 2 samples were analyzed more than 3 years after the shutdown of the reactors, only the long lived isotopes were detected. Blanks in tables indicate undetected isotopes or concentrations measured with poor statistical accuracy (error > 40%).

The Co-60 surface activity and Co-60 specific activity of the fixed oxide on the six feeder samples as well as on those removed earlier are presented in Figures 12-15.

A. **Inlet feeders:** The results show that after a decontamination (a) the Co-60 surface activity on the inlet feeders decreases considerably due to the removal of the fixed oxide (Figure 12), and (b) the average Co-60 specific activity of the fixed oxide decreases after the last decontamination in Units 1 and 2 (Figure 14). The decrease in Co-60 specific activity is caused by the removal of the "outer" oxide which has higher specific activity during the decontamination (also see Depth Profiles Section).

   Results in Figure 14 show that the Co-60 specific activity in the fixed oxide on the Unit 3 inlet feeder is similar to that on the Unit 2 V6 feeder. In addition, as discussed, the amount of oxide on the inlet feeder prior to the 1989 decontamination will likely be similar to that on the Unit 2 V6 feeder. Hence, the Co-60 radiation field contributed by the inlet feeders prior to the next Unit 3 decontamination is expected to be similar to that prior to the Unit 2 April 1984 decontamination.

B. **Outlet feeders:** The results are shown in Figures 13 and 15. It was suggested earlier that the high Co-60 surface activity and Co-60 specific activity in the fixed oxide on the Unit 1 V17 outlet feeder was caused by the deposition of

some higher specific activity, loose matter into the pits. This loose material, which would not easily be removed by ultrasonic cleaning was classified as fixed oxide/4/.

Figures 12 and 13 shows that for the Unit 1 V6 and Unit 3 V17 feeders that were exposed to operating conditions prior to removal the Co-60 surface activity on the inlet feeder is higher than that on the corresponding outlet feeder. However, for those removed after last Units 1 and 2 decontaminations, the reverse is true. This seems to suggest that the Co-60 field contributed by feeders is due mainly to the inlet feeders after operation and the outlet feeders after decontamination when less than 20 g/m^2 of oxide remains on the inlet feeders.

4. Depth Profiles

The depth profiling of elements and radioelements was obtained by following the procedures outlined in Reference 7. A feeder sample (about 25 cm^2) was first ultrasonic cleaned in acetone for 10 minutes. The loose particulate matter was then collected on a pre-weighed 0.45 um filter. The oxide surface of the feeder sample was then abraded with an X-acto knife in a glove box and the oxide was collected in a series of pre-weighed Petri dishes. It was attempted to collect more than 10 mg material in each dish. The process was stopped when the activity of the sample was reduced to 5-10% of its initial activity.

The loose particulates collected on filters and the materials collected in Petri dishes were first analyzed by gamma spectrometry to obtain the radioisotope concentration. Subsequently, the materials were dissolved in acid and analyzed using atomic absorption to obtain the concentrations of chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), nickel (Ni), manganese (Mn) and zinc (Zn).

The concentration of these elements in the base metal was also obtained so that one can compare the concentration of an element in the oxide and in the base metal. This in turn may identify the transport behaviour of this element ie whether the element diffuses out of the base metal or diffuses from solution into the oxide.

The major sources of error (uncertainty) in the depth profile results/8/ are the uncertainty in the weight of the scrapings, especially those samples that weighed less than 5 mg; and the presence of small amount of base metal in the scrapings of those feeders which have a thin oxide and a rough metal/oxide interface.

These errors can cause the calculated iron content of some samples to be considerably different from the expected value of magnetite (720,000 ppm) and the total amount of material scraped from Unit 1 and 2 samples to be significantly larger than the amount of oxide determined by chemical descaling. Note that

samples for the profile and chemical descaling were not necessarily cut from the adjacent section of the feeder pipe, hence, the possibility that the oxide is not uniformly distributed along the feeder could nct be ruled out.

To reduce the error in sample weight the profile results were adjusted so that the iron content for all samples was 720,000 ppm. This correction is based on the assumption that the scrapings do not contain any base metal which could increase the iron content of the samples. The revised results are presented in Tables 6 to 11 and Figures 16 and 19. Tables 12 and 13 summarize the corrected elemental profiles for easy comparison among various feeders. A blank in the table denotes the concentration is below the detection limit. The result of the loose oxide from Unit 1 V17 outlet feeder was missing because the sample was accidentally destroyed after the gamma scan was taken.

Since only three scrapings were collected from the Pickering 1 V17 inlet feeder, no trend can be established for this feeder. Furthermore, the cross-section of the Unit 1 V17 outlet feeder suggests that the scrapings collected may contain oxide from the surface and from the inside of the pits. Since these oxides may have different chemical compositions which were not characterized, these results were not included in the following discussion.

A. Radioelement depth profiles

a. Pickering 2 A12 inlet feeder: Both Co-60 and Sb-125 activity were higher in the loose oxide than in the fixed oxide. Also, the Co-60 and Sb-125 activities in the fixed oxide seem to peak near the water/oxide interface.

b. Pickering 2 V17 outlet feeder: Co-60 activity in the fixed oxide is higher at the surface (Figure 16).

c. Pickering 3 V17 inlet feeder: The Co-60 depth profile shows that the Co-60 specific activity is fairly constant at/near the water/oxide interface, and gradually decreases as the oxide/base metal interface is approached (Figure 17). In addition, the Co-60 specific activity at/near the surface is about 0.3 Ci/kg.

   The profiles for Nb-95 and Ce-144 (Figure 17) support the earlier finding that these isotopes are surface enriched/7/.

   Sb-124 was not detected due to the relatively high background caused by Co-60 (ie the activity of Sb-124 is low compared to Co-60).

d. Pickering 3 V17 outlet feeder: Figures 18 and 19 show that Ce-144, Co-60, Nb-95 and Sb-124 are all surface enriched on the thin outlet oxide.

In the earlier Unit 2 inlet feeders the Co-60 specific activity is lower at the water/oxide interface and then passes through a maximum (about 0.28 Ci/kg) as the oxide/base metal interface is approached/7/. It was also suggested that decontamination removes oxide at the water/oxide interface and leaves the oxide at the oxide/base metal interface undisturbed/7/. This in turn suggests that the peak Co-60 activity will be at or close to the water/oxide interface when the oxide on an inlet feeder is less than 20 um thick. This agrees with the above observations.

B. Elemental Depth Profiles

a. The Co concentration does not seem to vary greatly among the six specimens. The typical concentration is between 150 and 250 ppm; and it is similar to that found on the Unit 1 V6 and Unit 2 V17 inlet feeders/7/.

b. Very high level of Cr (20,000 ppm) was found on the loose oxide and on the oxide near the water/oxide interface of both Pickering 2 V17 and Pickering 3 V17 outlet feeders. The source of Cr is likely from stainless steel materials. Typical Cr concentration on the inlet feeders is about 500 to 800 ppm and is similar to the earlier feeder result/7/.

c. Cu concentrations of the loose oxide from the three inlet feeders (up to 13,000 ppm) are considerably higher than that from the outlet feeders. In addition, Cu seems to be surface enriched. The Cu concentrations in the fixed oxide on all of the specimens are higher than the earlier inlet feeder results (200-400 ppm)/7/.

Cu most likely originated from the Monel 400 (a Ni 70 - Cu 30 alloy) boiler tubes. Copper was previously detected along the walls of the pit in the Unit 1 V6 inlet feeder and it was suggested that the copper was in its elemental form/7/.

d. Mn seems to be quite evenly distributed in the fixed oxide. The typical concentration is around 4,000 ppm and is similar to the earlier inlet feeder result/7/.

e. Ni enrichment previously found near the oxide/base metal interface on the earlier inlet feeders/7/ was found near the water/oxide interface on the present samples probably due to the removal of overlaying oxide. This is similar to the Co-60 profile.

f. The Zn concentration generally is highest in the loose oxide and lowest in the base metal. In addition, the outlet feeder result clearly indicates Zn is enriched near the oxide/base metal interface. The enrichment is due mainly to the stability of zinc ferrite/7/. The earlier results showed that the Zn concentration is about 500 ppm in the oxide/7/.

In summary, (a) very high concentration of Cr was found in the loose oxide and in the oxide near the water/oxide interface on the outlet feeder; (b) high concentration of Cu was found on all feeder samples, especially on the inlet feeders; and its concentration is significantly higher than the value reported previously/7/; (c) high concentrations of Ni, Zn were found in the loose oxide and in the oxide near the water/oxide interface; and (d) the enrichment of Zn is found near the oxide/base metal interface on the outlet specimens.

It is known that nickel and zinc ferrites are more resistant than magnetite to acid dissolution/9/ and CAN-DECON decontamination solution is not effective in dissolving the chromium enriched oxides over about 70,000 ppm/10/. Therefore, the increase of Cu, Ni and Zn, especially Cr in the oxide close to the water/oxide interface could possibly contribute to the slow down of the oxide dissolution observed near the end of full scale decontaminations. Hence, an oxidizing step in between 2 CAN-DECON steps may improve the overall efficiency of a decontamination.

CONCLUSIONS

1. The amount of oxide on the Units 1 and 2 inlet feeders is very thin ($< 20\ g/m^2$) indicating the last decontaminations at these units effectively removed about 90% of oxide from the inlet feeders. It is expected that similar amount of oxide would be removed from the Unit 3 inlet feeders during the next decontamination if it behaves the same way as the oxide on Units 1 and 2.

2. Results show that residual Co-60 fields on feeders are due mainly to outlet feeders after a decontamination when less than 20 g/m^2 of oxide is left on the inlet feeders.

3. High concentrations of trace elements such as Cr, Cu, Ni and Zn found in the oxide near the water/oxide interface may contribute to the slow down of oxide dissolution observed near the end of the full scale decontamination. Hence, the inclusion of an oxidizing step may improve the effectiveness of a decontamination.

4. The depth profile results show that Co-60 is surface enriched after decontamination(s).

RECOMMENDATIONS

1. The effect of the presence of trace metals, especially Cr, Cu, Ni and Zn, at concentrations similar to those found on the feeders on the oxide dissolution in CAN-DECON solution should be determined. Their concentrations in feeder oxides should regularly be monitored. In addition, the deposition of Cr on carbon steel materials during decontamination should be confirmed in laboratory.

2. During the next CAN-DECON in Unit 3 detailed field survey should be conducted after each decontaminating stage to follow the change in activity on various surfaces.

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TABLE 1

OXIDE THICKNESS ON PICKERING FEEDERS

Inlet Feedeers

Unit	#	History	Loose Oxide (g/m^2)	Fixed Oxide (g/m^2)
1	V6	Exposed to the 1981 & 1983 decontaminations and 1 year of operation prior to removal	9.4	245.
1	V17	Exposed to the 1981, 1983 & 1984 decontaminations	1.5	8.3
2	V17	No exposure to decontamination	4.5	385.
2	V6	Exposed to the 1984 January decontamination	12.	215.
2	A12	Exposed to the January & April 1984 decontaminations	0.9	18.
3	V17	Exposed to the 1985 decontamination and 3 years of operation prior to removal	5.4	117.

Outlet Feeders

Unit	#	History	Loose Oxide (g/m^2)	Fixed Oxide (g/m^2)
1	V6	Exposed to the 1981 & 1983 decontaminations and 1 year of operation prior to removal	1.6	11.
1	V17	Exposed to the 1981, 1983 & 1984 decontaminations	4.	10.
2	V6	Exposed to the 1984 January decontamination	6.1	28.
2	V17	Exposed to the January & April 1984 decontaminations	3.6	15.
3	V17	Exposed to the 1985 decontamination and 3 years of operation prior to removal	4.	24.

TABLE 2

PICKERING UNIT 1 V17 INLET FEEDER
Decay corrected to Nov 14, 1983

Isotopes	Sp. Act, mCi/m^2	AVERAGE Loose Ci/kg	Fixed Ci/kg	Total Ci/kg
Am-241	0.0027	0.00042	0.00027	0.00029
Ba-140				
Ce-141				
Ce-144	0.080	0.022	0.0078	0.0097
Co-58				
Co-60	0.18	0.021	0.019	0.019
Cr-51				
Cs-134				
Cs-137	0.0045	0.00045	0.00046	0.00046
Eu-152				
Eu-154	0.0038		0.00046	0.00040
Fe-59				
La-140				
Mn-54				
Nb-95				
Zr-95				
Ru-103				
Ru-106	0.13	0.032	0.014	0.017
Sn-113				
Sb-124				
Sb-125	0.11	0.0094	0.012	0.012
Zn-65				

TABLE 3

PICKERING UNIT 2 A12 INLET FEEDER
Decay corrected to Aug 1, 1983

Isotopes	Sp. Act, mCi/m^2	AVERAGE Loose Ci/kg	Fixed Ci/kg	Total Ci/kg
Am-241	0.0044		0.00025	0.00024
Ba-140				
Ce-141				
Ce-144	0.25	0.056	0.011	0.013
Co-58				
Co-60	1.24	0.024	0.069	0.067
Cr-51				
Cs-134				
Cs-137	0.010	0.00037	0.00054	0.00053
Eu-152				
Eu-154	0.011	0.00080	0.00057	0.00059
Fe-59				
La-140				
Mn-54				
Nb-95				
Zr-95				
Ru-103				
Ru-106	0.39	0.0054	0.021	0.020
Sn-113				
Sb-124				
Sb-125	0.17	0.0034	0.0092	0.0090
Zn-65				

TABLE 4

PICKERING UNIT 3 V17 INLET FEEDER
Decay corrected to May 10, 1988

Isotopes	Sp. Act, mCi/m^2	AVERAGE Loose Ci/kg	Fixed Ci/kg	Total Ci/kg
Am-241				
Ba-140				
Ce-141	1.86	0.079	0.013	0.015
Ce-144	15.60	0.27	0.12	0.13
Co-58				
Co-60	21.82	0.086	0.19	0.18
Cr-51				
Cs-134	0.11	0.011	0.00044	0.00092
Cs-137	0.23	0.017	0.0012	0.0019
Eu-152				
Eu-154				
Fe-59	0.46	0.014	0.0035	0.0039
La-140	0.091	0.0064	0.00050	0.00076
Mn-54	0.32	0.0027	0.0027	0.0027
Nb-95	12.43	0.33	0.093	0.10
Zr-95	7.35	0.23	0.053	0.061
Ru-103	3.26	0.13	0.022	0.027
Ru-106	6.82	0.11	0.054	0.057
Sn-113				
Sb-124	0.038	0.0036	0.00016	0.00031
Sb-125	0.21	0.0024	0.0017	0.0017
Zn-65				

TABLE 5

PICKERING UNIT 3 V17 OUTLET FEEDER
Decay corrected to May 10, 1988

Isotopes	Sp. Act. mCi/m^2	AVERAGE Loose Ci/kg	Fixed Ci/kg	Total Ci/kg
Am-241				
Ba-140				
Ce-141	0.52	0.025	0.018	0.019
Ce-144	1.36	0.041	0.051	0.049
Co-58	0.014	0.00073	0.00046	0.00050
Co-60	0.71	0.038	0.024	0.026
Cr-51				
Cs-134	0.096	0.016	0.0014	0.0035
Cs-137	0.22	0.038	0.0031	0.0082
Eu-152				
Eu-154				
Fe-59	0.15	0.0067	0.0054	0.0056
La-140	0.048	0.0045	0.0013	0.0018
Mn-54	0.094	0.0057	0.0030	0.0034
Nb-95	1.55	0.096	0.049	0.056
Zr-95	0.78	0.056	0.024	0.028
Ru-103	1.08	0.077	0.033	0.039
Ru-106	0.50	0.036	0.015	0.018
Sn-113				
Sb-124	0.041	0.0021	0.0014	0.0015
Sb-125	0.085	0.0039	0.0029	0.0031
Zn-65				

TABLE 6 PICKERING UNIT 1 V17 INLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay corrected to April 19, 1988

	Loose Oxide	Scrapings 1	2	3 (closest to the basemetal)
Wt, mg	5.38	1.82	2.49	2.90
Ba-140				
Ce-141				
Ce-144	0.00084			
Co-58				
Co-60	0.019	0.00086	0.0011	0.00090
Cr-51				
Cs-134				
Cs-137	0.00089			
Eu-152				
Eu-154	0.00047			
Fe-59				
La-140				
Mn-54	0.00047			
Nb-95				
Zr-95				
Ru-103				
Ru-106	0.0027			
Sn-113				
Sb-124				
Sb-125	0.0039	0.00059	0.00056	0.00043
Zn-65	0.00082			

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000
Cr	1700	540	800	690
Mn	4700	4300	4000	4300
Co	180			
Ni	8700		920	690
Cu	10000	1800	2400	1800
Zn	1500	660	560	620

TABLE 7 PICKERING UNIT 1 V17 OUTLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay corrected to April 4, 1988

	Loose Oxide	Scrapings 1	2	3	4	5	6	(closest to) 7 (the basemetal)
Wt, mg		1.17	7.28	26.88	12.93	9.32	6.34	3.36
Ba-140								
Ce-141								
Ce-144								
Co-58								
Co-60		0.0033	0.0029	0.0012	0.0012	0.0013	0.0012	0.00089
Cr-51								
Cs-134								
Cs-137		0.000063	0.000037	0.000022	0.000021	0.000017	0.000022	
Eu-152								
Eu-154								
Fe-59								
La-140								
Mn-54								
Nb-95								
Zr-95								
Ru-103								
Ru-106			0.00023	0.000096	0.00012		0.000087	
Sn-113								
Sb-124								
Sb-125		0.00099	0.0010	0.00040	0.00040	0.00043	0.00037	0.00027
Zn-65								

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000	720000	720000	720000
Cr	850	820	560	470	540	490	590
Mn	5100	4700	4400	3800	4700	6100	4600
Co		140	190	150	210	240	
Ni	850	1300	670	550	640	490	300
Cu	1300	1200	970	780	1200	2100	4000
Zn	1500	3000	290	210	1500	4300	420

TABLE 8 PICKERING UNIT 2 A12 INLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay corrected to April 14, 1988

	Loose Oxide	Scrapings 1	2	3	4	5	6	(Closest to) 7 (the basemetal)
Wt, mg	1.66	6.15	6.68	18.63	14.00	13.80	18.79	23.03
Ba-140								
Ce-141								
Ce-144								
Co-58								
Co-60	0.021	0.0041	0.0087	0.0036	0.0060	0.0027	0.0024	0.0018
Cr-51								
Cs-134								
Cs-137	0.00052							
Eu-152								
Eu-154								
Fe-59								
La-140								
Mn-54								
Nb-95								
Zr-95								
Ru-103								
Ru-106	0.0012							
Sn-113								
Sb-124								
Sb-125	0.0024	0.00052	0.00096	0.00041	0.00064	0.00031	0.00025	0.00018
Zn-65								

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000	720000	720000	720000	720000
Cr	3000	650	760	800	720	800	540	610
Mn	4300	3800	4000	4100	3900	4400	4500	4400
Co		160	140	170	140	140	430	180
Ni	3500	1100	1200	1000	890	800	640	600
Cu	13000	3100	4700	3700	3000	2800	2300	1800
Zn	3900	1300	1300	150	170	1200	680	120

TABLE 9 PICKERING UNIT 2 V17 OUTLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay corrected to April 4, 1988

	Loose Oxide	Scrapings 1	2	3	4	5	6	7	8	9	(closest to) 10 (the basemetal)
Wt, mg	13.99	0.82	0.70	7.65	23.72	15.21	31.93	27.62	19.30	22.21	29.14
Ba-140											
Ce-141											
Ce-144											
Co-58											
Co-60	0.15	0.16	0.12	0.041	0.021	0.020	0.013	0.0075	0.0087	0.0051	0.0041
Cr-51											
Cs-134											
Cs-137	0.0013	0.0018	0.00092	0.00020	0.00010	0.000069					
Eu-152	0.00022										
Eu-154	0.00061			0.00012	0.000064						
Fe-59											
La-140											
Mn-54											
Nb-95											
Zr-95											
Ru-103											
Ru-106		0.0023		0.00061	0.00022		0.00018				
Sn-113											
Sb-124											
Sb-125	0.018	0.034	0.022	0.0067	0.0030	0.0027	0.0018	0.00092	0.0010	0.00056	0.00043
Zn-65											

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000	720000	720000	720000	720000	720000	720000	720000
Cr	20000	7200	5700	1600	1100	850	880	650	670	674	690
Mn	5600	6200	11000	4500	3800	4500	3800	4000	4600	4686	4200
Co	150			260	210	260	190	210	210	183	170
Ni	3200	18000	11000	4600	2300	1930	1400	900	840	674	580
Cu	2200	3300	21000	7100	3400	2700	1900	1200	1200	949	860
Zn	2900	2600	2400	660	190	390	130	150	1000	651	190

TABLE 10 PICKERING UNIT 3 V17 INLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay Corrected to April 28, 1988

	Loose Oxide	Scrapings 1	2	3	4	5	6	7	8	(closest to) 9 (the basemetal)
Wt, mg	1.10	11.59	9.65	28.70	45.89	27.84	47.18	50.05	50.37	47.36
Ba-140										
Ce-141	0.11	0.080	0.065	0.047	0.028	0.017	0.0052	0.0015	0.00059	0.00017
Ce-144	0.33	0.51	0.44	0.30	0.21	0.12	0.035	0.0085	0.0026	0.00089
Co-58	0.0015	0.0016	0.0013	0.0012						
Co-60	0.18	0.34	0.33	0.32	0.29	0.23	0.11	0.049	0.024	0.0093
Cr-51	0.019	0.018	0.012							
Cs-134	0.0022	0.0016	0.0016	0.0014		0.0019	0.00057			0.000038
Cs-137	0.0046	0.0036	0.0036	0.0031	0.0026	0.0031	0.0012	0.00052	0.00020	0.000084
Eu-152										
Eu-154	0.0013	0.0020	0.0017							
Fe-59	0.011	0.015	0.012	0.0097	0.0065	0.0042	0.0024	0.00052	0.00034	0.00015
La-140	0.0047	0.0031	0.0026	0.0029	0.0021	0.0016	0.00073	0.00025	0.00013	0.000051
Mn-54	0.0041	0.0060	0.0061	0.0058	0.0043	0.0032	0.0014	0.00045	0.00023	0.000099
Nb-95	0.41	0.49	0.39	0.28	0.14	0.097	0.030	0.0065	0.0023	0.00071
Zr-95	0.28	0.30	0.24	0.17	0.080	0.058	0.018	0.0039	0.0013	0.00041
Ru-103	0.17	0.14	0.11	0.084	0.036	0.026	0.0081	0.0019	0.00076	0.00024
Ru-106	0.17	0.21	0.17	0.14	0.096	0.058	0.017	0.0042	0.0015	0.00048
Sn-113	0.0015									
Sb-124	0.00072									
Sb-125	0.0035	0.0043	0.0033	0.0037	0.0035	0.0039				
Zn-65		0.0023								

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000	720000	720000	720000	720000	720000	720000
Cr	2700	860	900	800	870	720	530	500	480	430
Mn	4500	2800	3000	3100	3100	3500	3800	4800	4800	4900
Co		260	320	280	260	260	200	170	150	130
Ni	9100	6900	7200	9700	9700	8600	4300	2400	600	630
Cu	7700	9500	8300	5500	4300	2900	1500	800	640	460
Zn	3200	320	600	150	130	140	90	120	80	60

TABLE 11 PICKERING UNIT 3 V17 OUTLET FEEDER

CORRECTED RADIOISOTOPE DEPTH PROFILE (Ci/kg), Decay Corrected to April 28, 1988

	Loose Oxide	Scrapings								(closest to)
		1	2	3	4	5	6	7	8	9	10 (the basemetal)
Wt, mg	3.60	2.75	4.71	7.48	16.49	18.38	19.21	20.83	19.54	29.31	29.11
Ba-140		0.0014	0.00091	0.00074	0.00015	0.00043	0.00046	0.00032	0.00020	0.00012	
Ce-141	0.028	0.016	0.0090	0.0071	0.0013	0.0035	0.0040	0.0030	0.0014	0.00087	0.00087
Ce-144	0.12	0.034	0.02	0.015	0.0028	0.0075	0.0083	0.0062	0.0031	0.0019	0.0018
Co-58	0.0013	0.00040	0.00021	0.00016	0.000035	0.000084	0.000076	0.000061	0.000036	0.000020	0.000019
Co-60	0.089	0.021	0.011	0.0086	0.0018	0.0040	0.0036	0.0028	0.0023	0.0013	0.0011
Cr-51	0.012	0.0025	0.0016	0.0013	0.00025	0.00049	0.00054				
Cs-134	0.0055		0.0017			0.00066			0.00029	0.00018	
Cs-137	0.014	0.0079	0.0043	0.0034	0.00074	0.0017	0.0015	0.0011	0.00073	0.00046	0.00040
Eu-152											
Eu-154			0.00014								
Fe-59	0.0048	0.0050	0.0027	0.0022	0.00049	0.0011	0.00095	0.00070	0.00045	0.00029	0.00024
La-140	0.00054	0.0018	0.0010	0.00081	0.00020	0.00045	0.00049	0.00035	0.00019	0.00013	0.00011
Mn-54	0.0061	0.0031	0.0016	0.0013	0.00027	0.00064	0.00054	0.00040	0.00027	0.00017	0.00014
Nb-95	0.18	0.060	0.032	0.025	0.0049	0.011	0.0095	0.0070	0.0043	0.0027	0.0021
Zr-95	0.11	0.030	0.016	0.013	0.0025	0.0055	0.0048	0.0036	0.0022	0.0013	0.0011
Ru-103	0.11	0.043	0.022	0.018	0.0032	0.0073	0.0068	0.0050	0.0029	0.0018	0.0015
Ru-106	0.073	0.017	0.0082	0.0069	0.0013	0.0027	0.0025	0.0018	0.0011	0.00071	0.00064
Sn-113			0.00011	0.000085		0.000048					
Sb-124	0.0027	0.0017	0.00090	0.00071	0.00013	0.00030	0.00026	0.00019	0.00011	0.000078	0.000049
Sb-125	0.0097	0.0031	0.0016	0.0012	0.00025	0.00054	0.00053	0.00034	0.00022	0.00011	0.000088
Zn-65			0.00014	0.000095		0.000067				0.000027	

CORRECTED ELEMENTAL DEPTH PROFILE (ppm)

Fe	720000	720000	720000	720000	720000	720000	720000	720000	720000	720000	720000
Cr	19000	26000	880	670	300	710	570	570	520	520	510
Mn	1700	6600	2900	3200	2300	5100	5000	5000	4700	4300	4300
Co					60	160	150	180	150	170	170
Ni	2200	3200	880	810	250	550	510	480	410	340	350
Cu	560	1500	1000	540	250	530	500	570	490	490	500
Zn	940	1100	430	350	110	160	130	770	720	140	100

TABLE 12 CORRECTED PICKERING FEEDER ELEMENTAL PROFILES (ppm)
(Grouped according to the Unit)

		Loose	Scraping									
		Oxide	1	2	3	4	5	6	7	8	9	10	Basemetal
Co	P1V17 In	180											120
Co	P1V17 Out	-		140	190	150	210	240					110
Co	P2A12 In		160	140	170	140	140	430	180				150
Co	P2V17 Out	170			260	210	260	190	210	210	180	170	110
Co	P3V17 In		260	320	280	260	260	200	170	150	130		310
Co	P3V17 Out					60	160	150	180	150	170	170	100
Cr	P1V17 In	1700	540	810	700								1100
Cr	P1V17 Out	-	850	820	560	470	540	490	590				690
Cr	P2A12 In	2300	650	760	800	720	800	540	610				820
Cr	P2V17 Out	20000	7200	5700	1600	1100	850	880	650	670	680	690	800
Cr	P3V17 In	2700	860	940	840	870	720	530	500	480	430		740
Cr	P3V17 Out	19000	26000	880	670	300	710	570	570	520	520	510	760
Cu	P1V17 In	10000	1800	2400	1800								550
Cu	P1V17 Out	-	1300	1200	970	780	1200	2100	4000				550
Cu	P2A12 In	13000	3100	4700	3700	3000	2800	2300	1800				470
Cu	P2V17 Out	2200	3300	21000	7100	3400	2700	1900	1200	1200	950	860	600
Cu	P3V17 In	7700	9500	8200	5500	4300	2900	1500	800	640	460		540
Cu	P3V17 Out	560	1500	1000	500	250	530	500	570	500	490	500	500
Mn	P1V17 In	4700	4300	4000	4300								5700
Mn	P1V17 Out	-	5100	4700	4400	3800	4700	6100	4600				6400
Mn	P2A12 In	4300	3800	4000	4100	3900	4400	4500	4400				5700
Mn	P2V17 Out	5600	6200	11000	4500	3800	4500	3800	4000	4600	4700	4200	6000
Mn	P3V17 In	4500	2800	3000	3100	3100	3500	3800	4800	4800	4900		6500
Mn	P3V17 Out	1700	6600	2900	3200	2300	5100	5000	5000	4700	4300	4300	6300
Ni	P1V17 In	8700		920	690								370
Ni	P1V17 Out	-	850	1300	670	550	640	490	300				320
Ni	P2A12 In	3500	1100	1200	1000	890	800	640	600				260
Ni	P2V17 Out	3200	18000	11000	4600	2300	1900	1400	910	840	670	580	440
Ni	P3V17 In	9100	6900	7200	9700	9700	8600	4300	2400	600	630		310
Ni	P3V17 Out	2200	3200	880	810	250	550	510	480	410	340	350	280
Zn	P1V17 In	1500	660	560	620								30
Zn	P1V17 Out	-	1500	3000	290	210	1500	4300	420				36
Zn	P2A12 In	3900	1300	1300	150	170	1200	680	120				33
Zn	P2V17 Out	2900	2600	2400	660	190	390	130	150	1000	650	190	31
Zn	P3V17 In	3200	320	600	150	130	140	90	120	80	60		38
Zn	P3V17 Out	940	1100	430	350	110	160	130	770	720	140	100	38

TABLE 13 CORRECTED PICKERING FEEDER ELEMENTAL PROFILES (ppm)
(Grouped according to the nature of the feeders)

		Loose Oxide	Scraping 1	2	3	4	5	6	7	8	9	10	Basemetal
Co	P1V17 In	180											120
Co	P2A12 In		160	140	170	140	140	430	180				150
Co	P3V17 In		260	320	280	260	260	200	170	150	130		310
Co	P1V17 Out	-		140	190	150	210	240					110
Co	P2V17 Out	170			260	210	260	190	210	210	180	170	110
Co	P3V17 Out					60	160	150	180	150	170	170	100
Cr	P1V17 In	1700	540	810	700								1100
Cr	P2A12 In	2300	650	760	800	720	800	540	610				820
Cr	P3V17 In	2700	860	940	840	870	720	530	500	480	430		740
Cr	P1V17 Out	-	850	820	560	470	540	490	590				690
Cr	P2V17 Out	20000	7200	5700	1600	1100	850	880	650	670	680	690	800
Cr	P3V17 Out	19000	26000	880	670	300	710	570	570	520	520	510	760
Cu	P1V17 In	10000	1800	2400	1800								550
Cu	P2A12 In	13000	3100	4700	3700	3000	2800	2300	1800				470
Cu	P3V17 In	7700	9500	8200	5500	4300	2900	1500	800	640	460		540
Cu	P1V17 Out	-	1300	1200	970	780	1200	2100	4000				550
Cu	P2V17 Out	2200	3300	21000	7100	3400	2700	1900	1200	1200	950	860	600
Cu	P3V17 Out	560	1500	1000	500	250	530	500	570	500	490	500	500
Mn	P1V17 In	4700	4300	4000	4300								5700
Mn	P2A12 In	4300	3800	4000	4100	3900	4400	4500	4400				5700
Mn	P3V17 In	4500	2800	3000	3100	3100	3500	3800	4800	4800	4900		6500
Mn	P1V17 Out	-	5100	4700	4400	3800	4700	6100	4600				6400
Mn	P2V17 Out	5600	6200	11000	4500	3800	4500	3800	4000	4600	4700	4200	6000
Mn	P3V17 Out	1700	6600	2900	3200	2300	5100	5000	5000	4700	4300	4300	6300
Ni	P1V17 In	8700		920	690								370
Ni	P2A12 In	3500	1100	1200	1000	890	800	640	600				260
Ni	P3V17 In	9100	6900	7200	9700	9700	8600	4300	2400	600	630		310
Ni	P1V17 Out	-	850	1300	670	550	640	490	300				320
Ni	P2V17 Out	3200	18000	11000	4600	2300	1900	1400	910	840	670	580	440
Ni	P3V17 Out	2200	3200	880	810	250	550	510	480	410	340	350	280
Zn	P1V17 In	1500	660	560	620								30
Zn	P2A12 In	3900	1300	1300	150	170	1200	680	120				33
Zn	P3V17 In	3200	320	600	150	130	140	90	120	80	60		38
Zn	P1V17 Out	-	1500	3000	290	210	1500	4300	420				36
Zn	P2V17 Out	2900	2600	2400	660	190	390	130	150	1000	650	190	31
Zn	P3V17 Out	940	1100	430	350	110	160	130	770	720	140	100	38

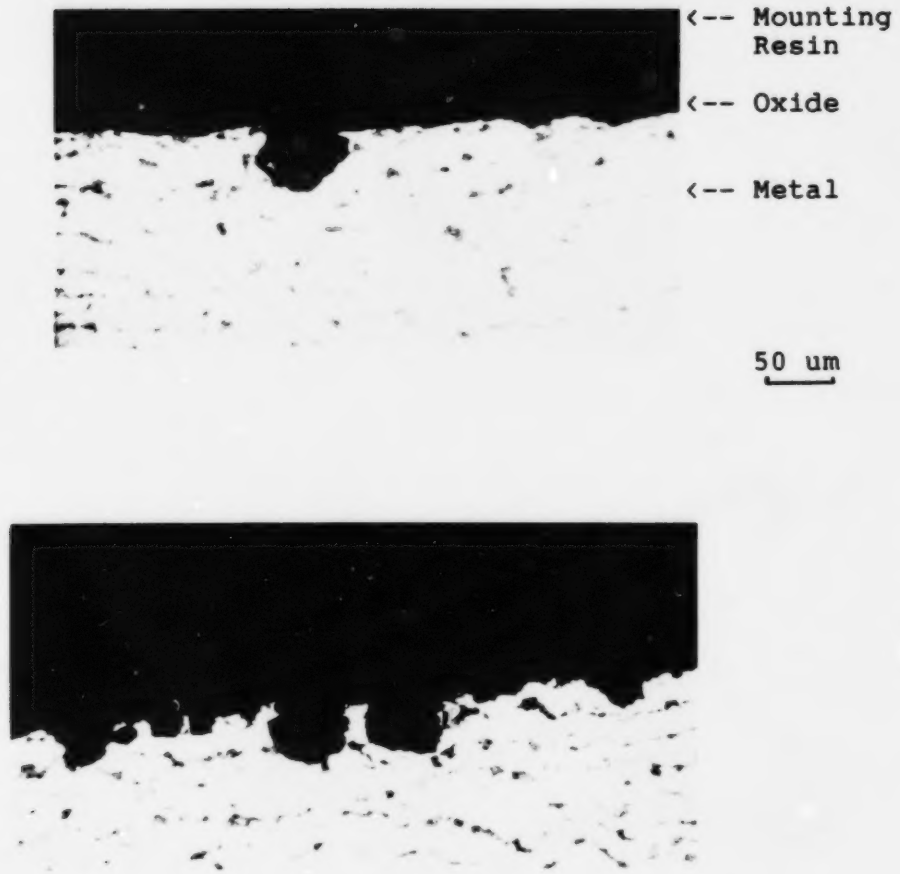

FIGURE 1 CROSS-SECTIONS OF PICKERING UNIT 1 V17 INLET (TOP) AND V17 OUTLET FEEDERS (BOTTOM) (200 X)

FIGURE 2 CROSS-SECTIONS OF PICKERING UNIT 2 A12 INLET (TOP) AND V17 OUTLET FEEDERS (BOTTOM) (200 X)

FIGURE 3 CROSS-SECTIONS OF PICKERING UNIT 3 V17 INLET (TOP) AND V17 OUTLET FEEDERS (BOTTOM) (200 X)

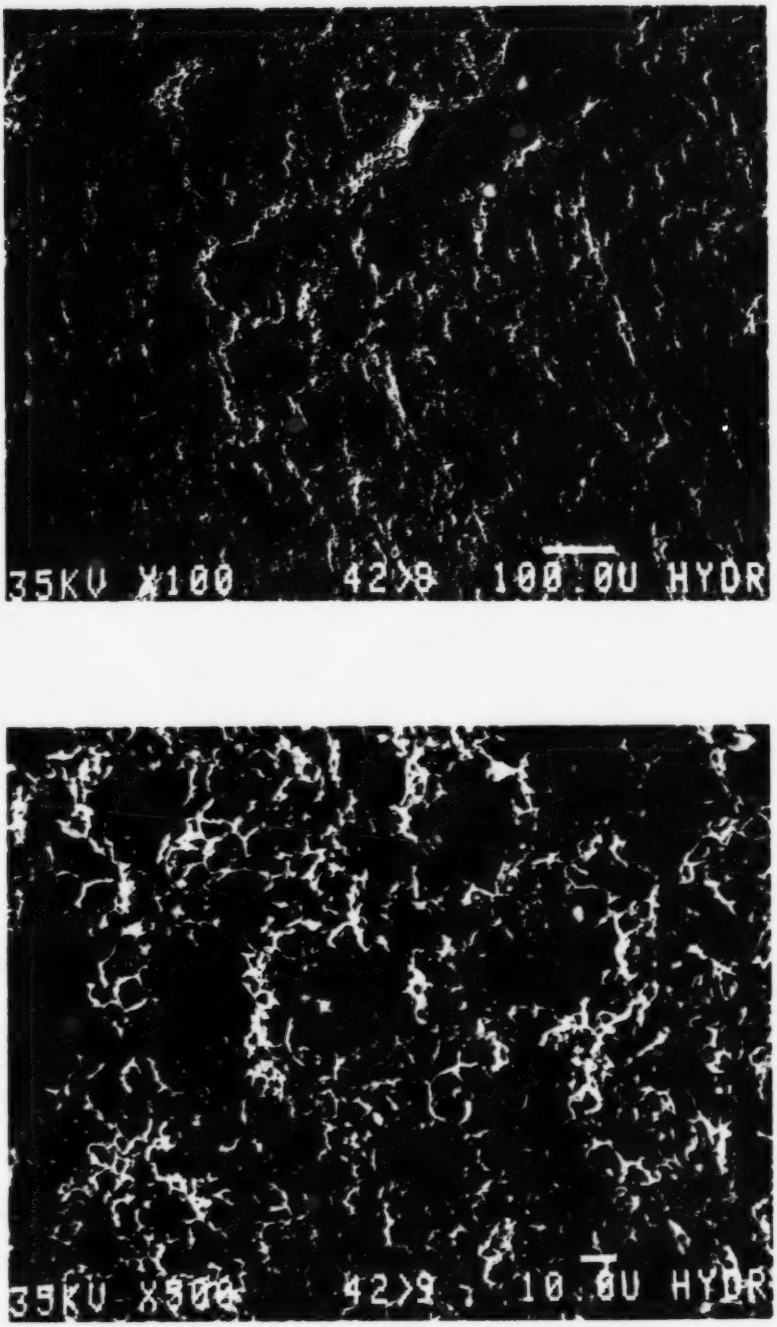

FIGURE 4 SEM MICROGRAPHS OF PICKERING UNIT 1 V17 INLET FEEDER (TOP 100 X, BOTTOM, 500 X)

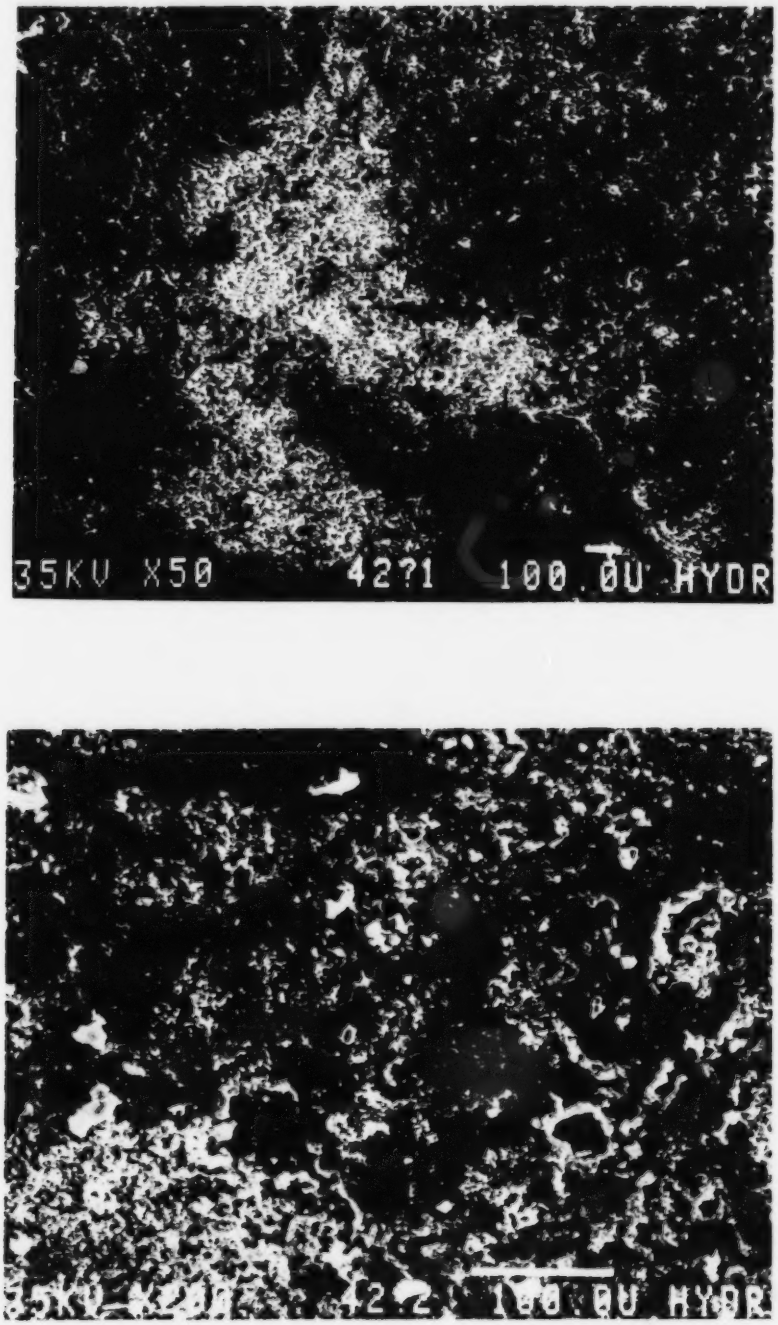

FIGURE 5 SEM MICROGRAPHS OF PICKERING UNIT 1 V17 OUTLET FEEDER (TOP 50 X, BOTTOM, 200 X)

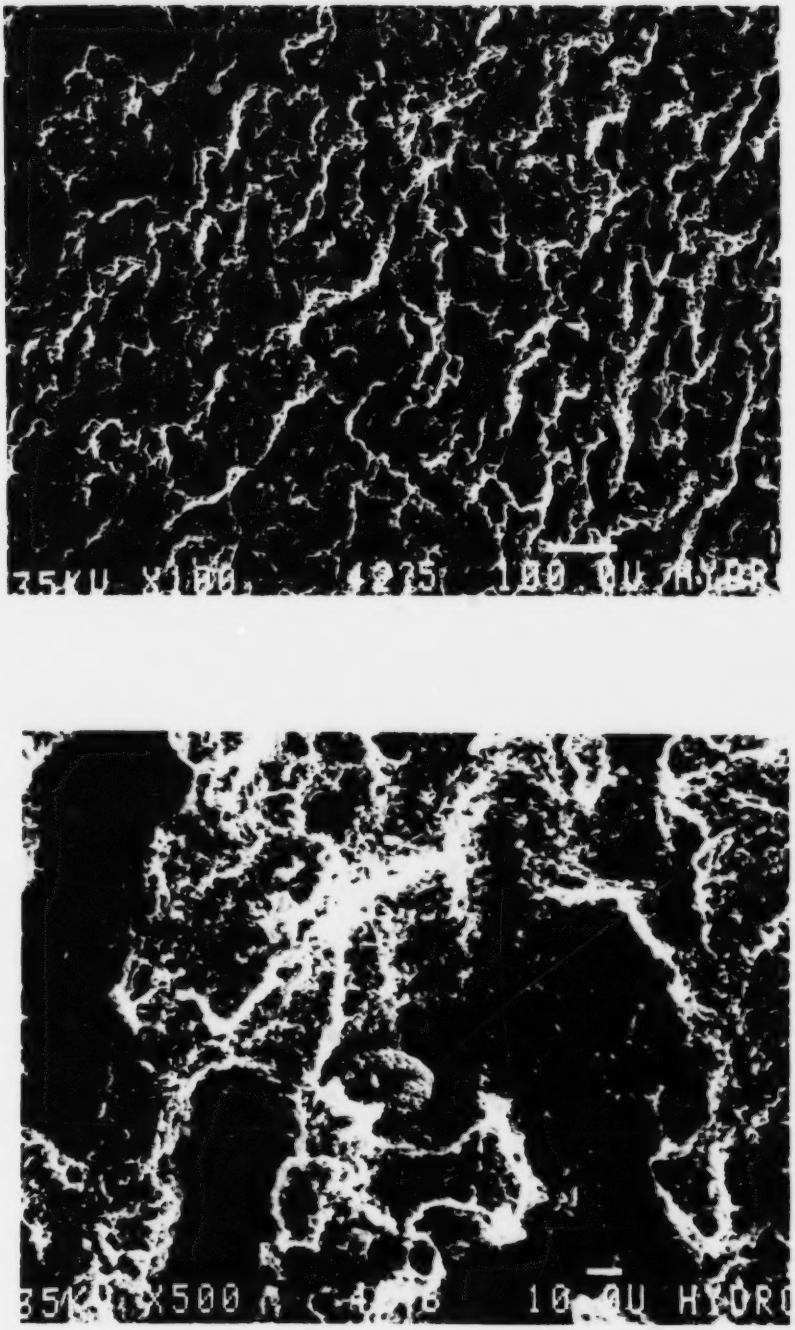

FIGURE 6 SEM MICROGRAPHS OF PICKERING UNIT 2 A12 INLET FEEDER (TOP 100 X, BOTTOM, 500 X)

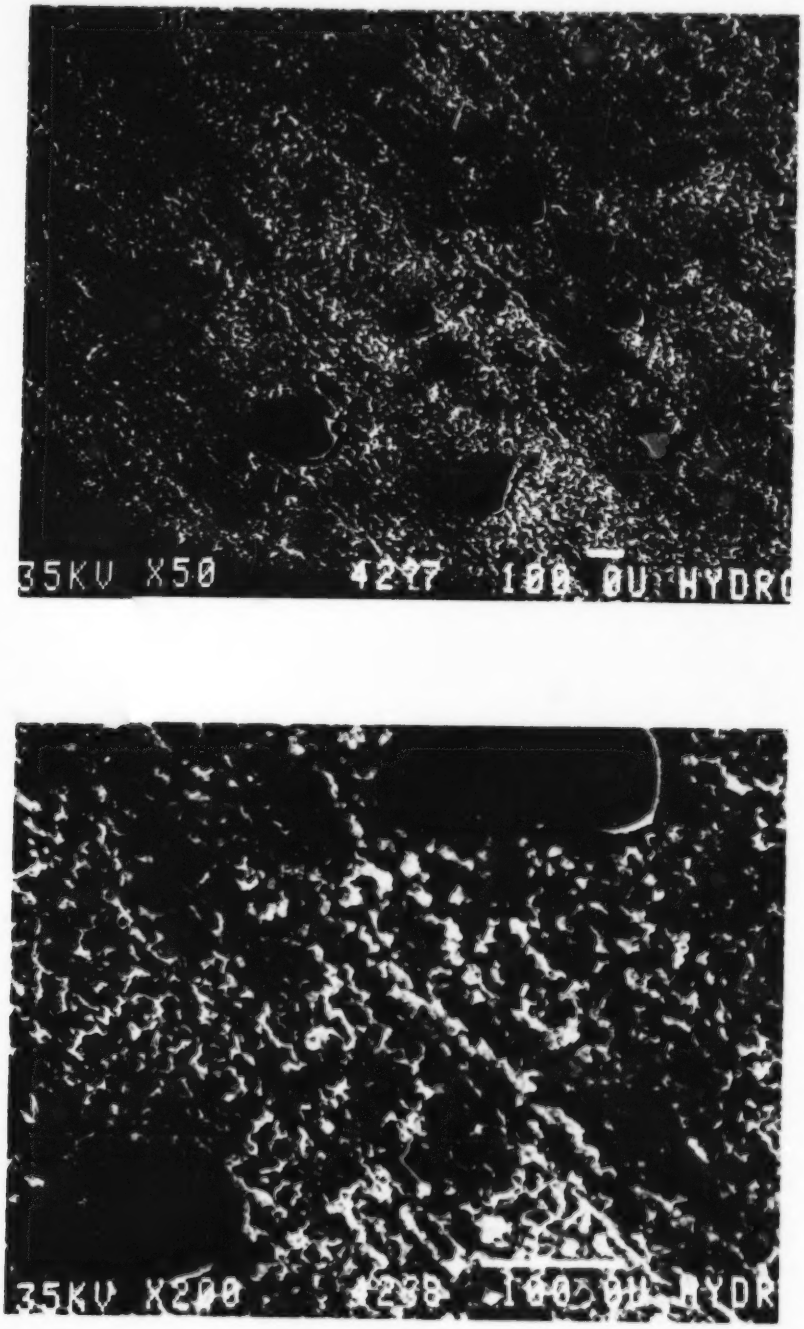

FIGURE 7 SEM MICROGRAPHS OF PICKERING UNIT 2 V17 OUTLET FEEDER (TOP 50 X, BOTTOM, 200 X)

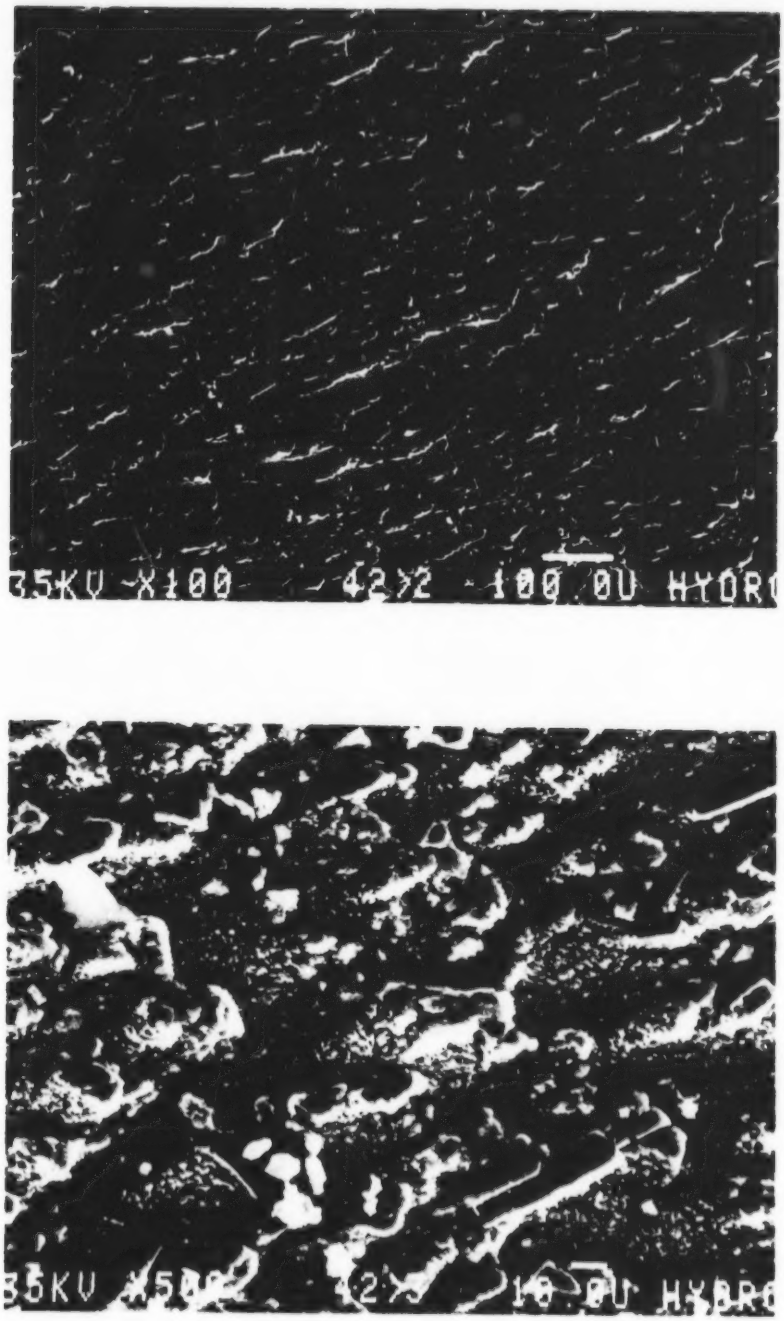

FIGURE 8 SEM MICROGRAPHS OF PICKERING UNIT 3 V17 INLET FEEDER (TOP 100 X, BOTTOM, 500 X)

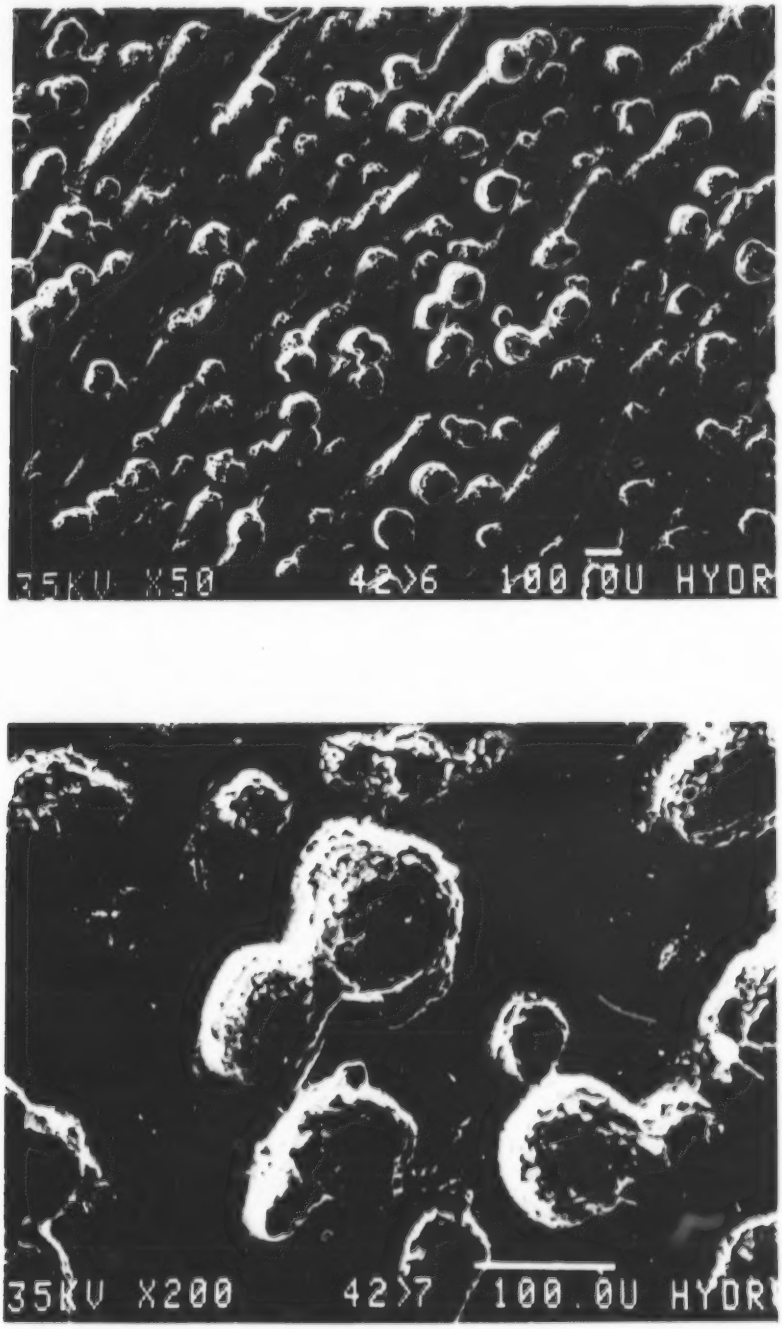

FIGURE 9 SEM MICROGRAPHS OF PICKERING UNIT 3 V17 OUTLET FEEDER (TOP 50 X, BOTTOM, 200 X)

FIGURE 10 THE AMOUNT OF OXIDE ON PICKERING INLET FEEDERS

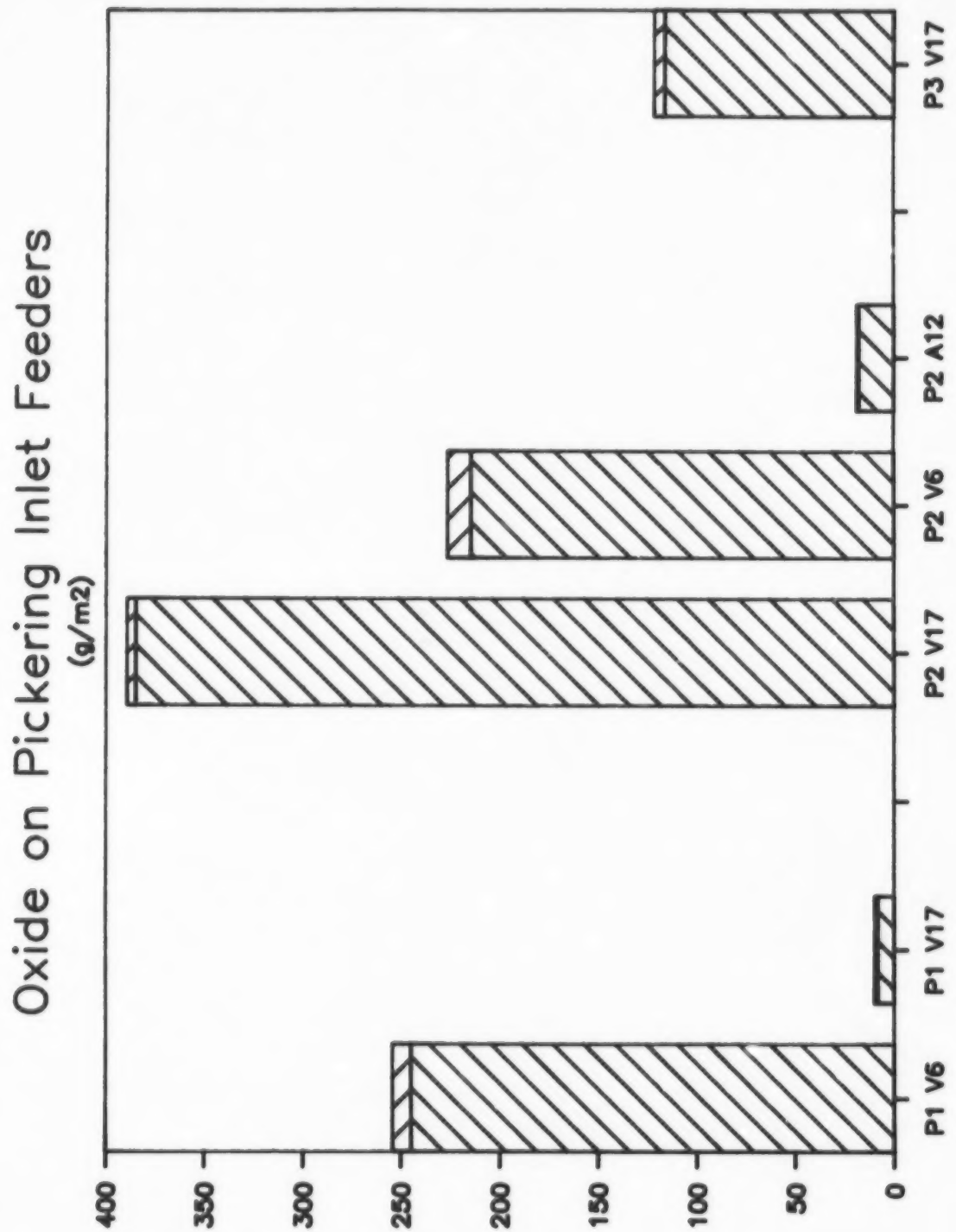

FIGURE 11 THE AMOUNT OF OXIDE ON PICKERING OUTLET FEEDERS

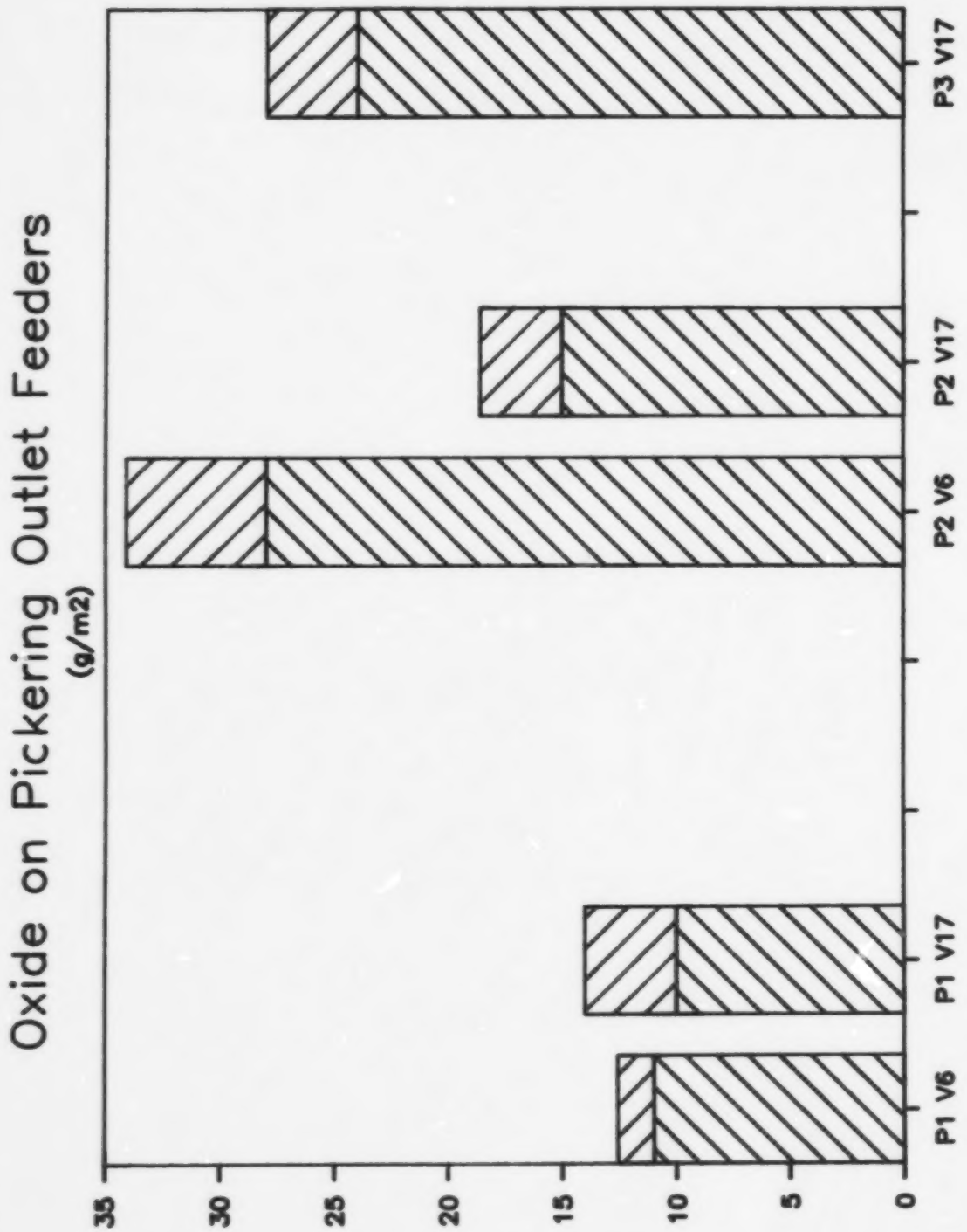

FIGURE 12 Co-60 SURFACE ACTIVITY ON PICKERING INLET FEEDERS

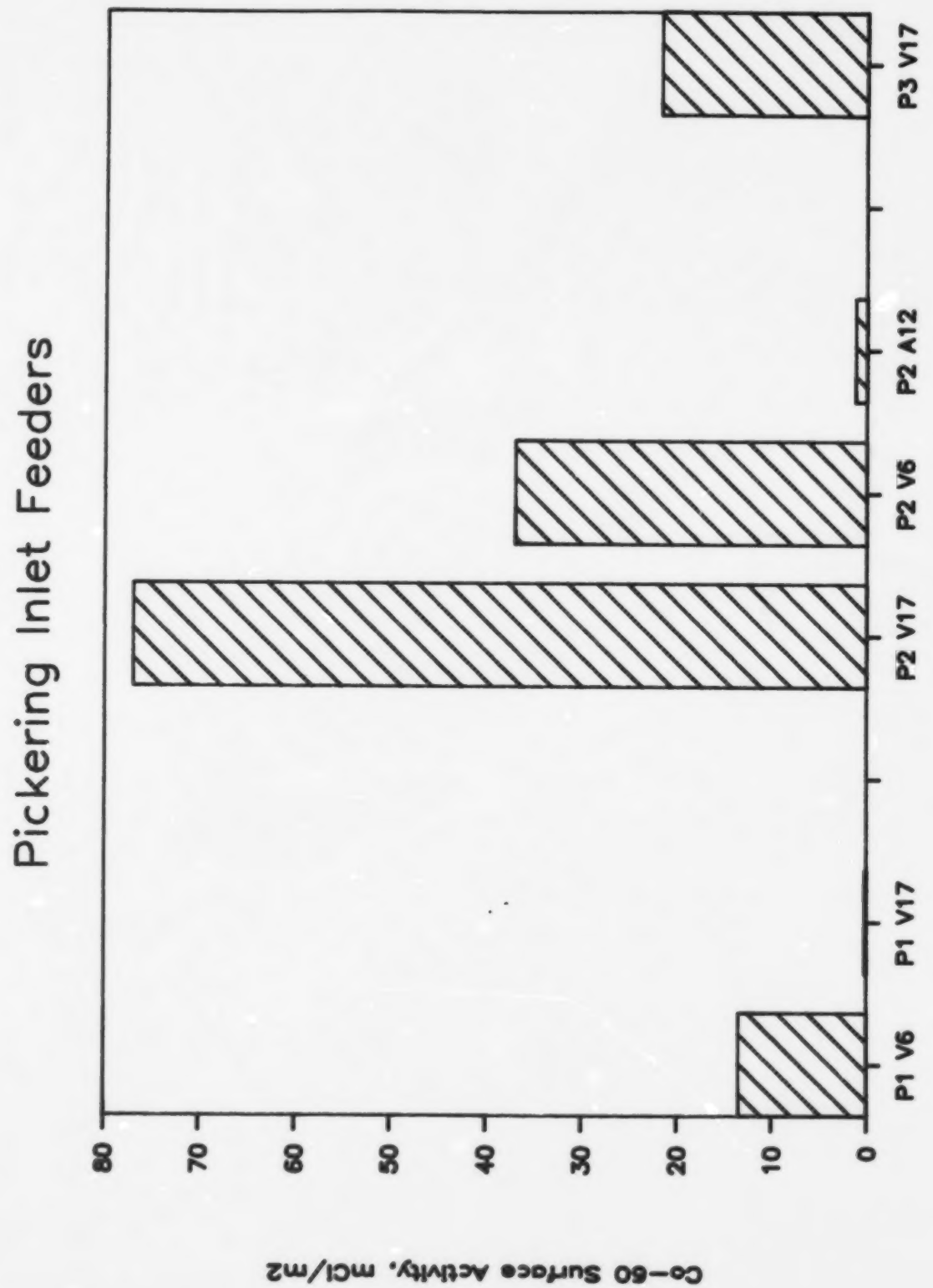

FIGURE 13 Co-60 SURFACE ACTIVITY ON PICKERING OUTLET FEEDERS

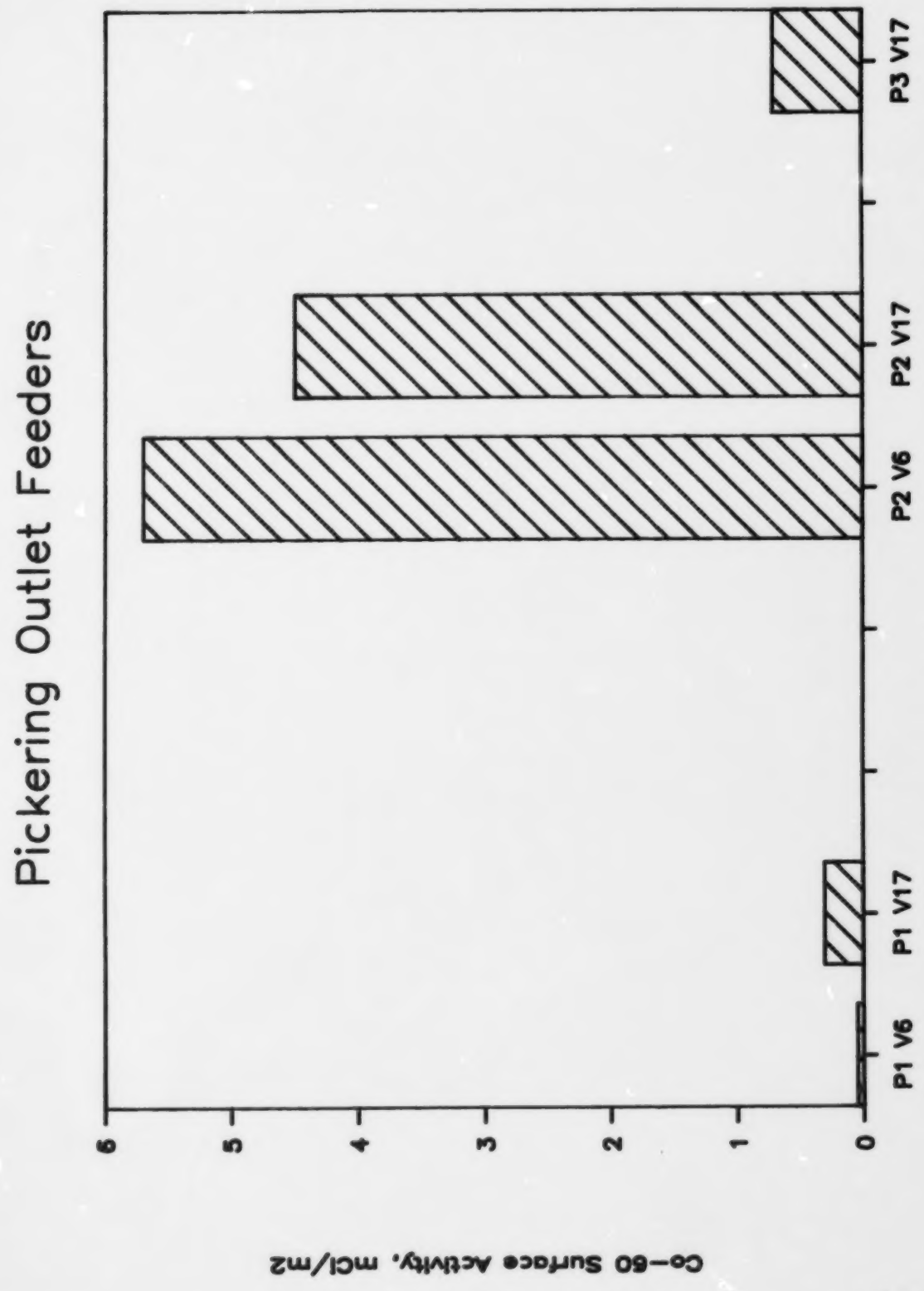

FIGURE 14 Co-60 SPECIFIC ACTIVITY OF FIXED OXIDE ON PICKERING INLET FEEDERS

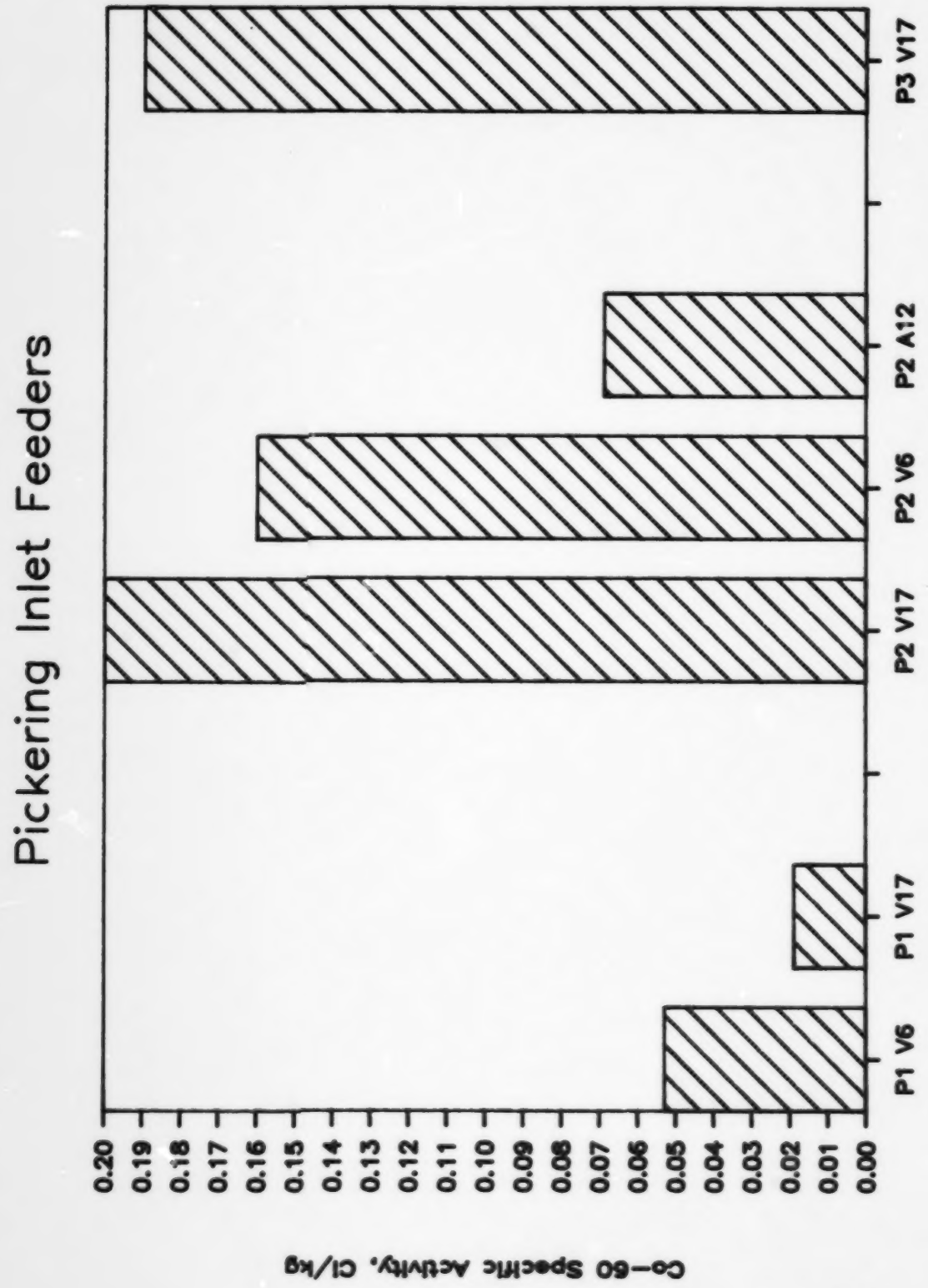

FIGURE 15 Co-60 SPECIFIC ACTIVITY OF FIXED OXIDE ON PICKERING OUTLET FEEDERS

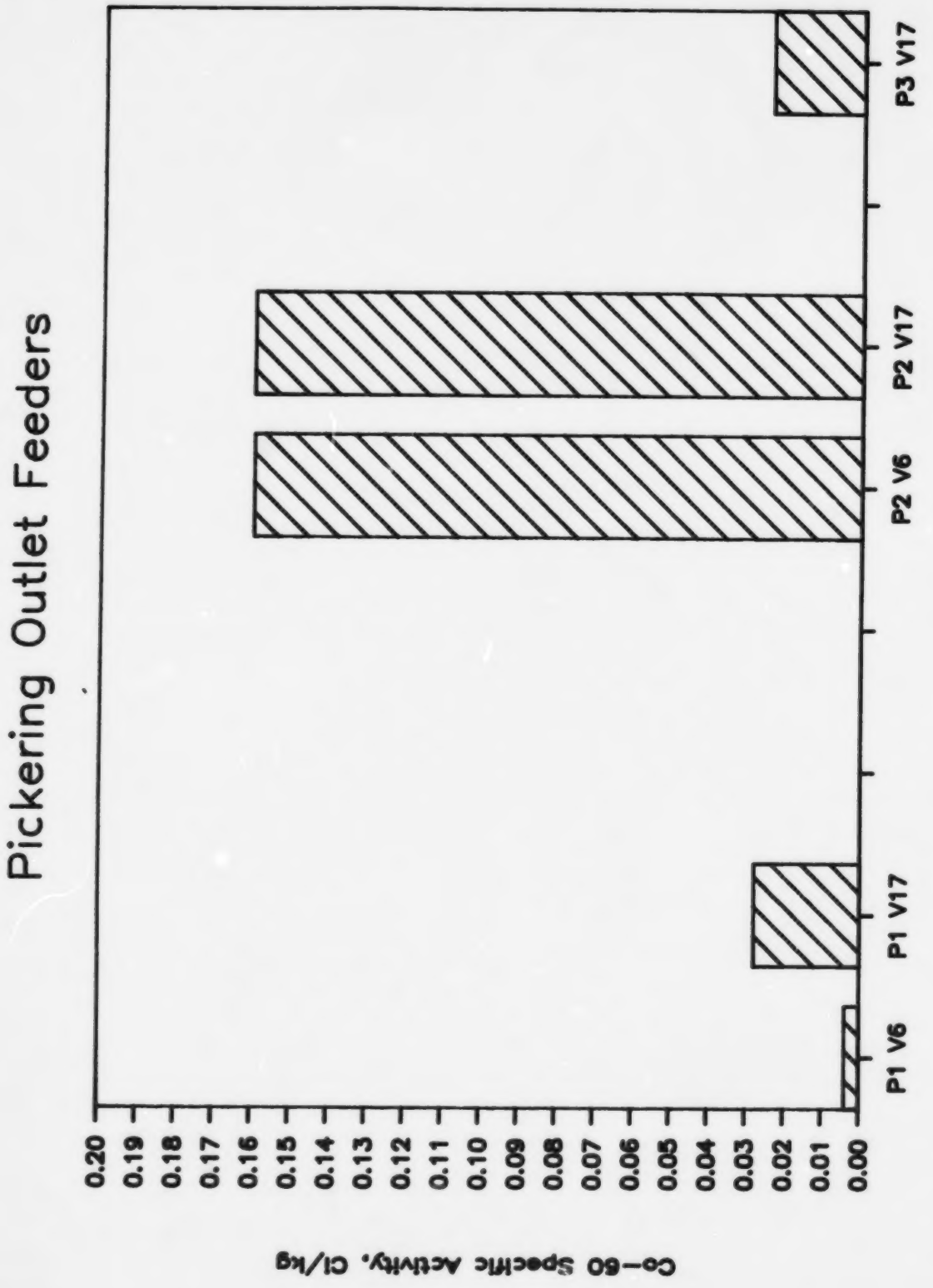

FIGURE 16 Co-60 DEPTH PROFILE OF PICKERING 2 V17 OUTLET FEEDER

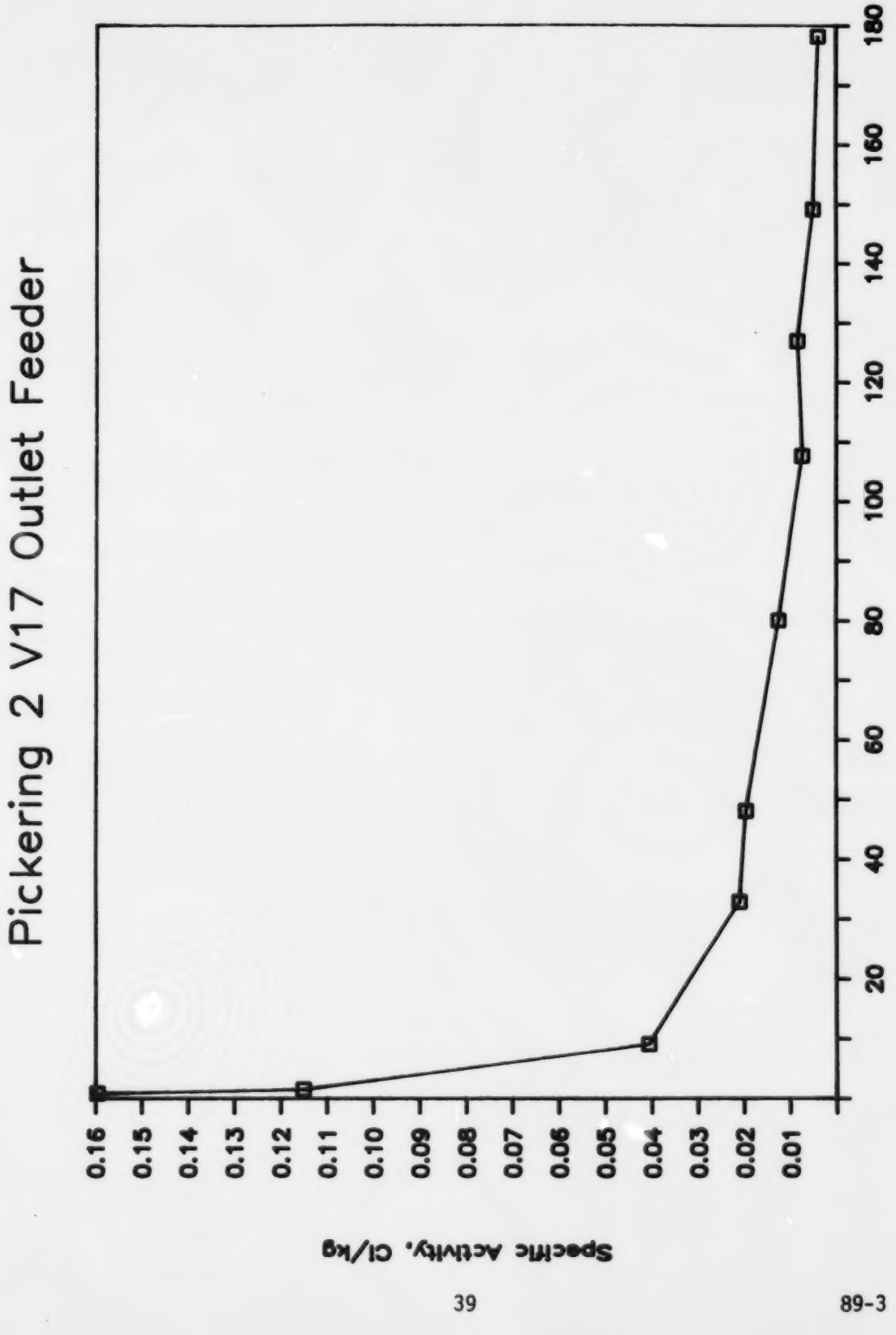

FIGURE 17 Co-60, Nb-95 and Ce-144 DEPTH PROFILES OF PICKERING 3 V17 INLET FEEDER

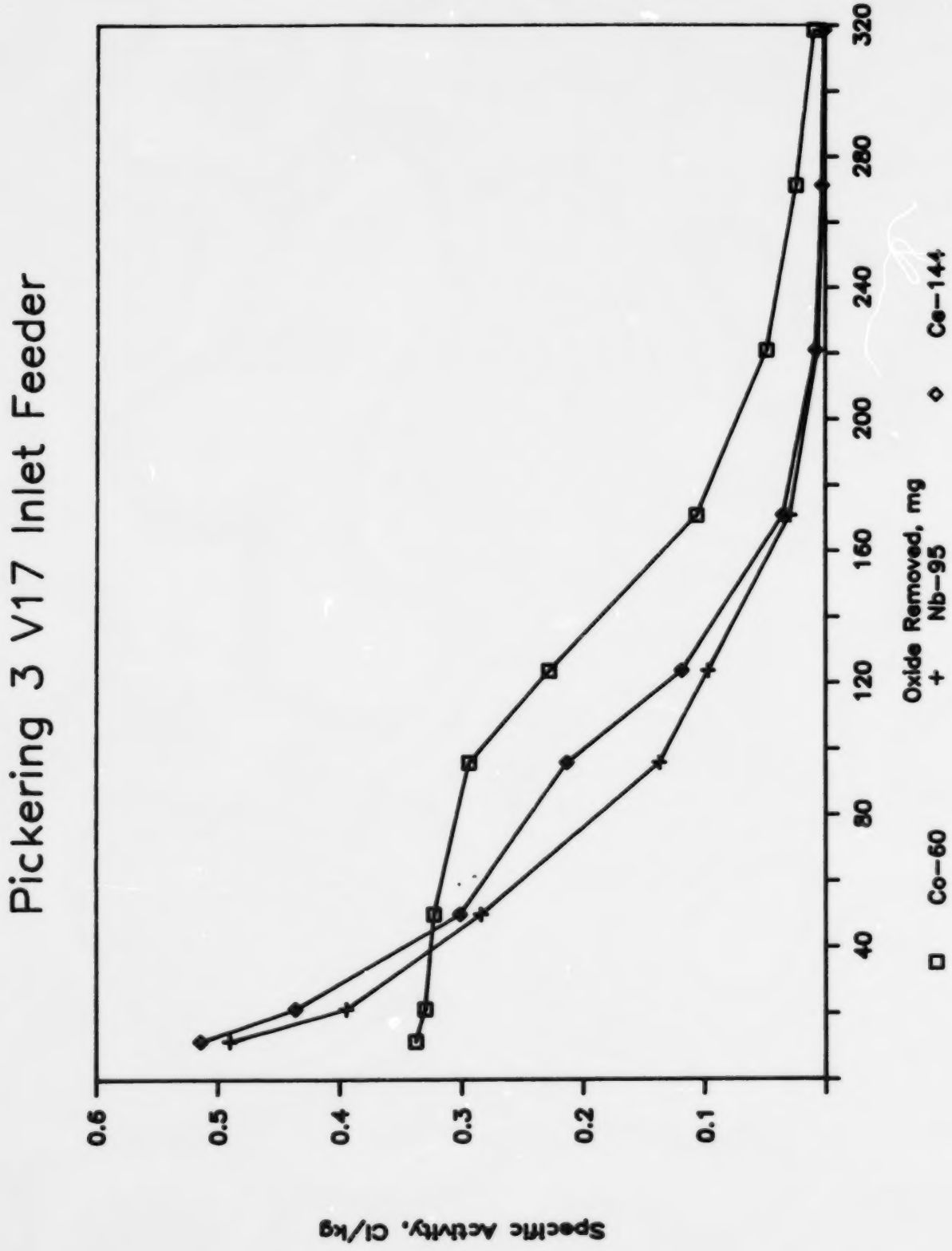

FIGURE 18 Co-60, Nb-95 and Ce-144 DEPTH PROFILES OF PICKERING 3 V17 OUTLET FEEDER

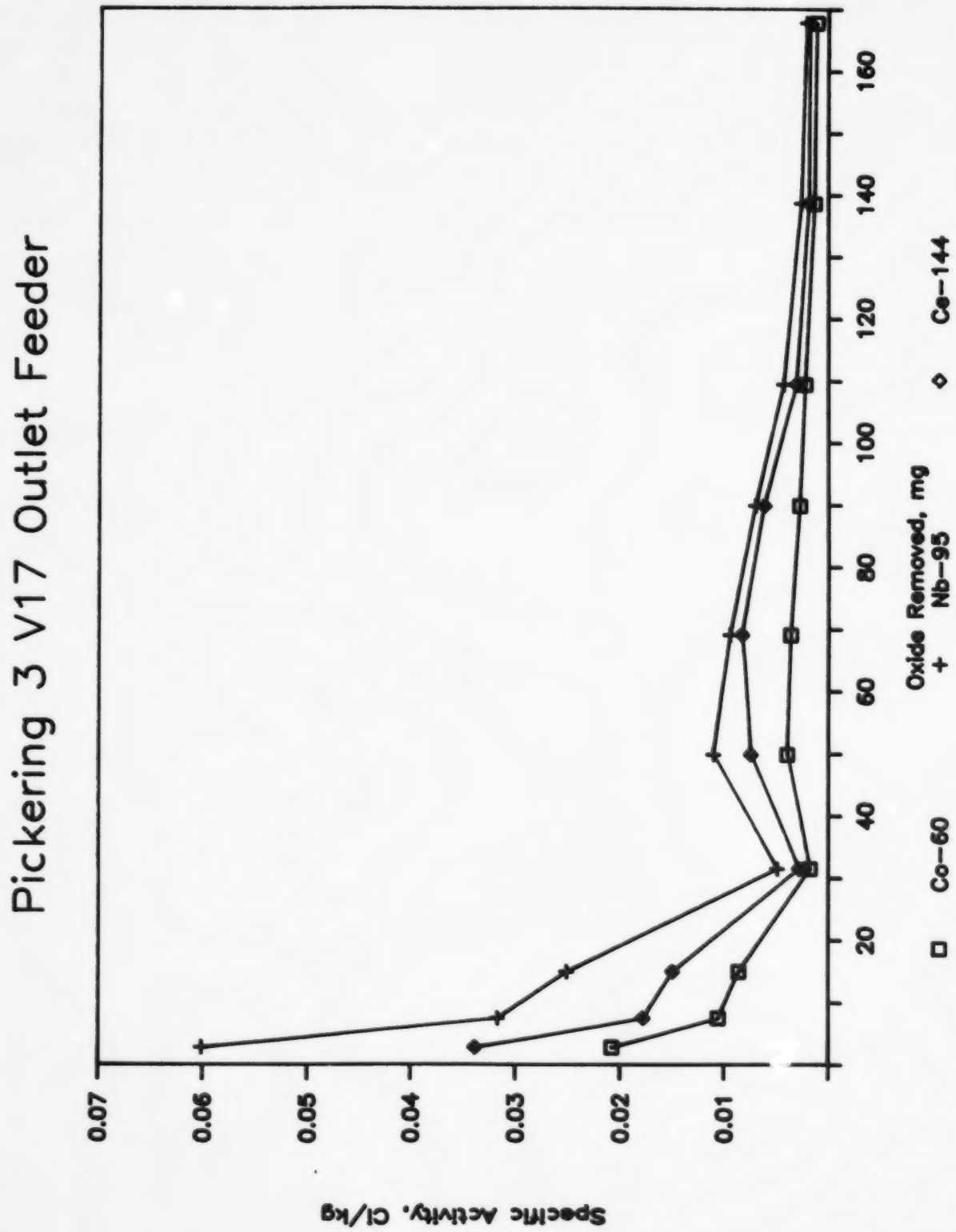

FIGURE 19 Sb-124 DEPTH PROFILE OF PICKERING 3 V17 OUTLET FEEDER